Characterization of PXIE MEBT scraper prototype

- Project X & PXIE
- MEBT & scrapers
- Test stand
- Calibration and analysis
- Data processing
- Estimations for PXIE
- Summary

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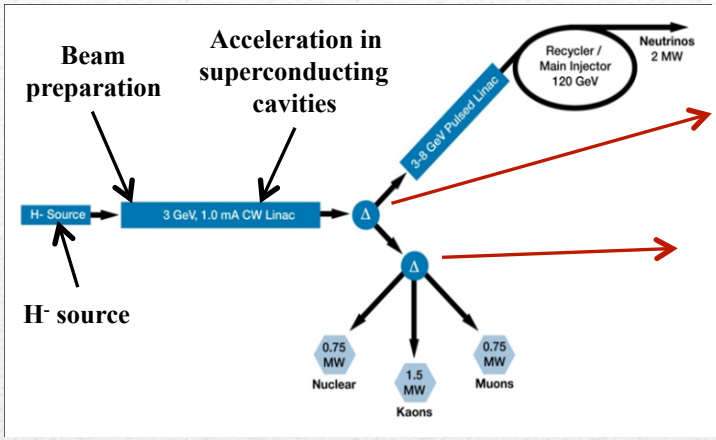
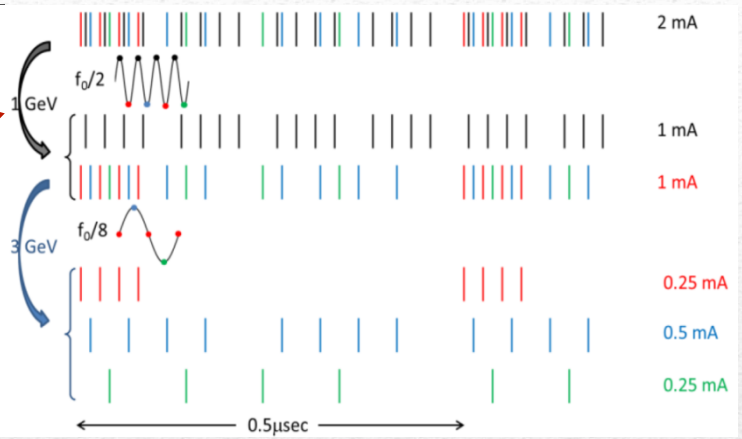
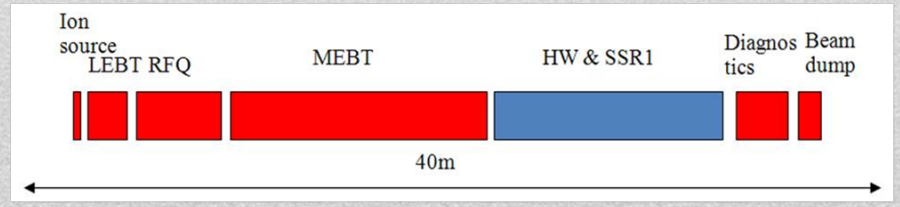
Scheme of the Project X



Separation particles between different experiments

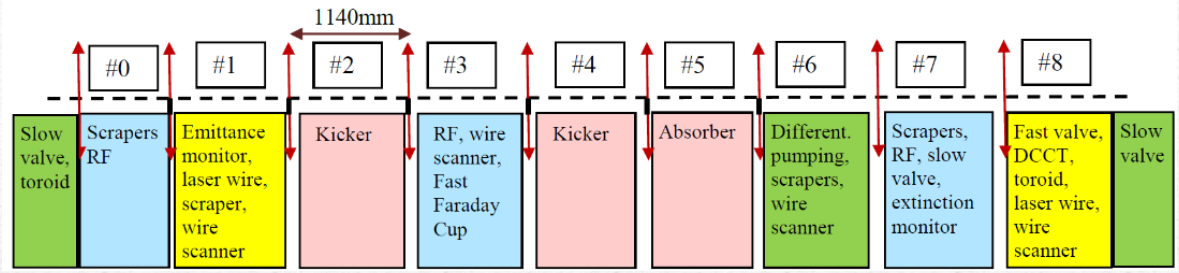


- Project X is a new accelerator based on superconducting accelerating cavities.
- CW beam structure
- High beam power: 21 kW in MEBT, 3-8 MW in high-beta sections.
- Superconducting cavities needs protecting from beam power.



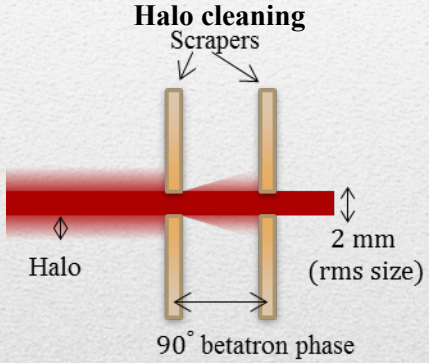
PXIE is designed to prove the Project X main concept

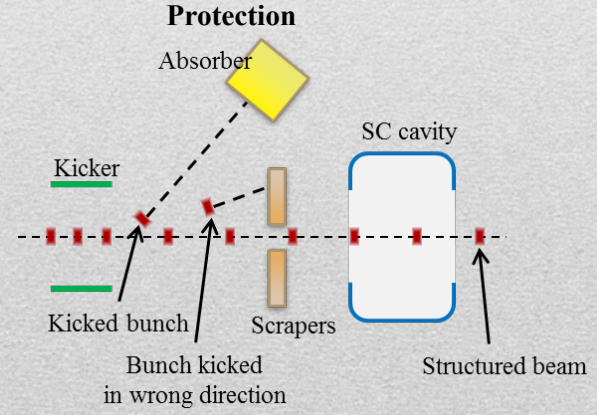
Beam preparations are performed in MEBT. Scrapers are for halo cleaning and beam protection.



Beam input parameters

Ion type	H^-
Beam current\energy	10mA \ 2.1MeV
RMS beam radius	2 mm





Preferences for scrapers:

Number of scrapers	**16**
Maximum average power per scraper	100 W
Electrically isolated	

Radiation cooled scraper:

To estimate the reached temperature, $W_{absorbed} = \varepsilon \sigma T^4 S$

ε – emissivity, $S = 45\ cm^2$ – emitting area

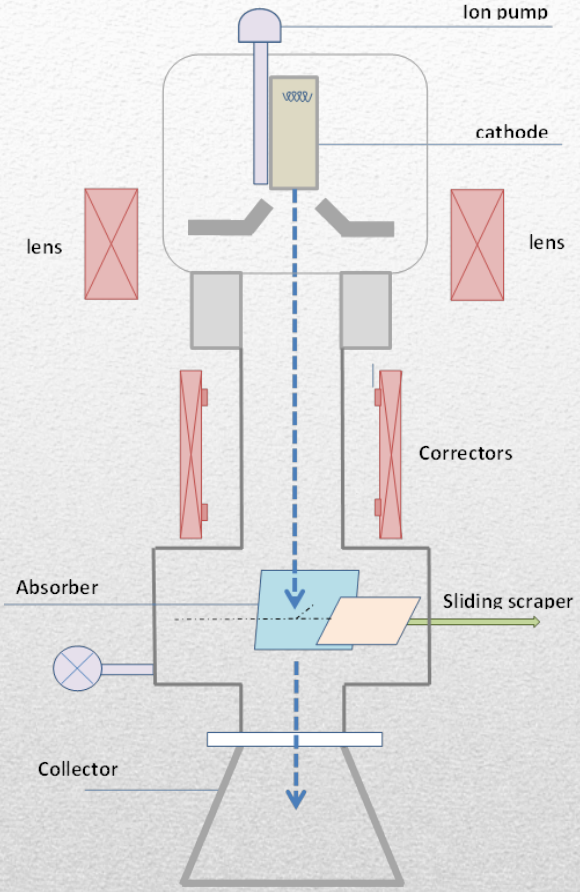
$W_{absorbed} = 100\ W$; $\varepsilon = 0.1 \Rightarrow$ In steady state: $T_{ss} = 1200\ K$

Might be feasible to use such scraper in PXIE!

MEBT and scrapers

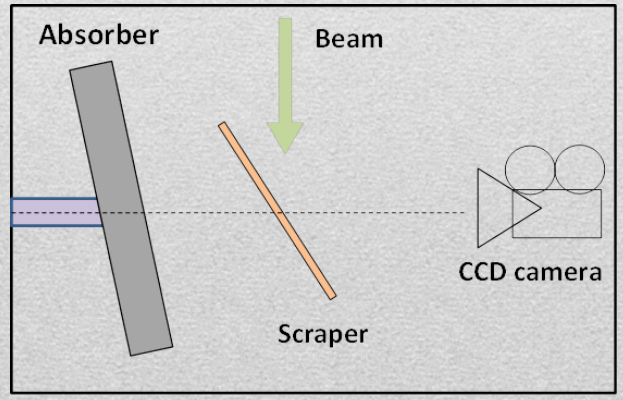
- To simulate the scraper thermal regime for PXIE, the scraper emissivity must be measured.
- To test scraper, the e-beam will be used.
- On the test stand, the beam power reflection coefficient is unknown and needs measuring too.
- To do these measurements, the diagnostics must be designed:
  - Analyzing of the beam position and size
    - Necessary to use it in simulations
  - Temperature measurements
    - To use it as a protection system in PXIE
    - To compare with simulated results
- Thermal regime simulation
    - To adjust unknown parameters
    - To estimate the temperatures for arbitrary beam parameters

Goals



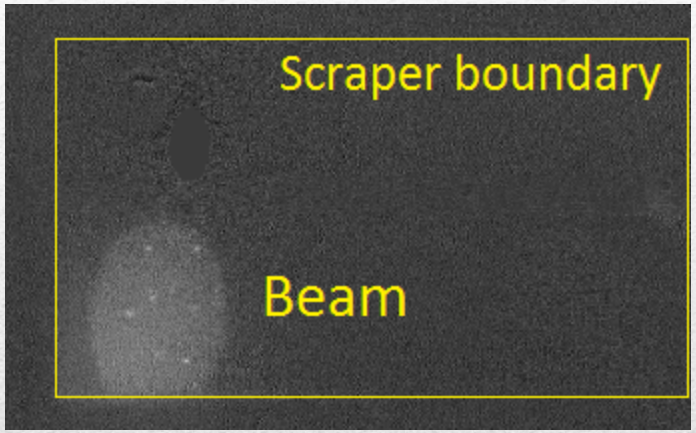
- To test the scraper prototype, the test stand represented on the picture will be used.
- An **e**-beam is accelerated to the scraper \ absorber and can be moved and focused
  - allows to make a beam with different power density.
- The absorber
  - has water cooling and thermocouples for temperature measurements and located $9.4°$ apart from the vertical position
- Scraper
  - Only way of the scraper cooling is heat radiation. The scraper slope amounts to $32°$.
- Scraper and absorber are made from molybdenum alloy called TZM.
  - TZM has high heat diffusivity and high melt point (about $2500°C$)

The beam falling on the absorber or scraper, the heat and OTR radiation appear. To measure it, the CCD camera is used.



Test stand

- To measure the beam sizes and position on the scraper, OTR light was used
  - The difficult was the too bright cathode light



- Heat radiation measurements were performed with narrow band red filter
- The transmission wavelength is 710 nm

Accordingly the Wien's distribution law, the emitted intensity depends on surface temperature like

$$I(\nu,T) = \frac{2h\nu^3}{c^2} e^{\frac{-h\nu}{kT}} \quad \text{or} \quad I(T) = I_0 e^{\frac{-T_{eff}}{T}}$$

For selected wavelength $T_{eff} = 20350K$

$I \downarrow 0$ can't be easy calculated.

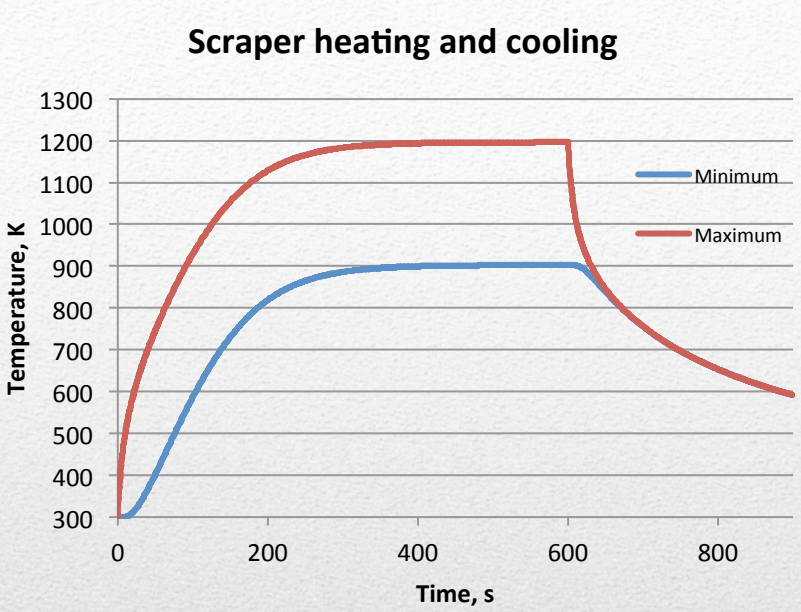
As a solution, some points on plot were taken as initial:

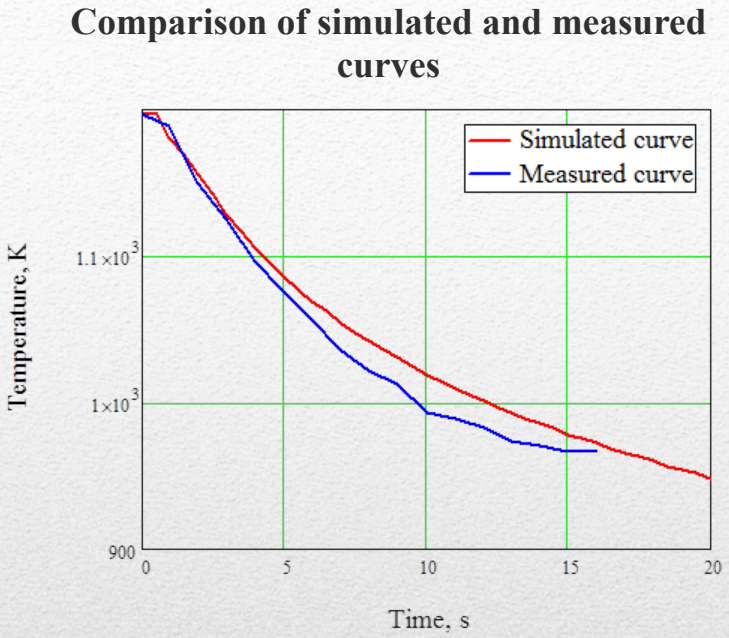
the maximal measured intensity was compared with maximal calculated temperature. Then, the temperature can be restored by the following formula

$$T(I) = \frac{T_i T_{eff}}{T_{eff} + T_1 \ln(I_i / I)}$$

Calibration and analysis

Comparison of the simulated and measured temperature behavior during the cooling



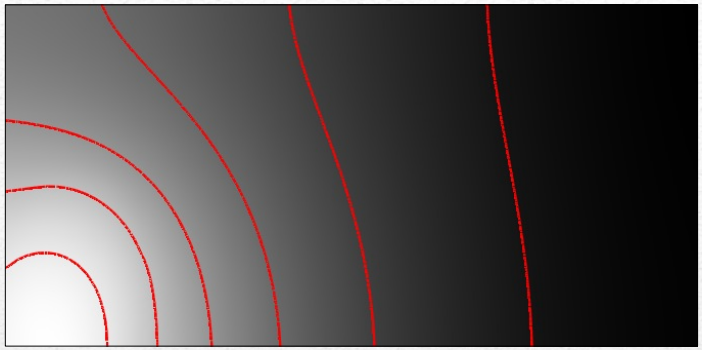


- The intensity was measured in the area inside the beam. The temperature had to be constant along that area and equal to the maximal temperature.
- Then, the measured curve was converted into the temperature and compared with curve of maximal simulated temperature.
- The best simulated curve was made with emissivity coefficient **~0.2** and the beam power reflection **~20%.**

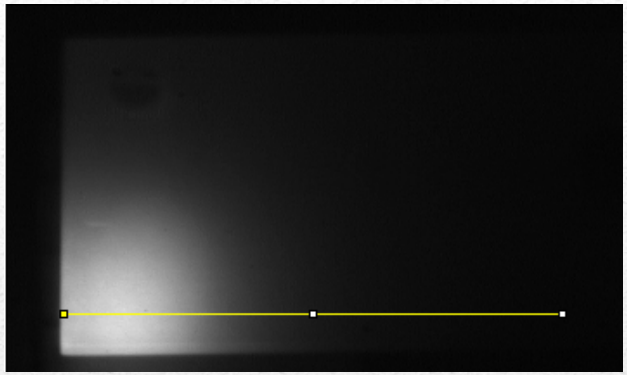
Data processing

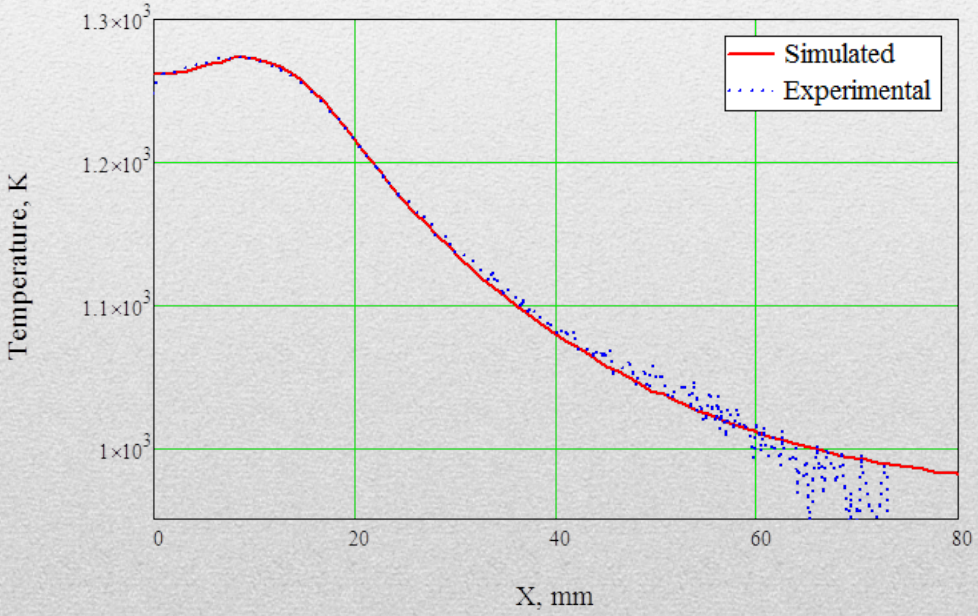
Comparison of the simulated model and measured temperature distribution

Simulated scraper thermal regime



Snapshot of the scraper



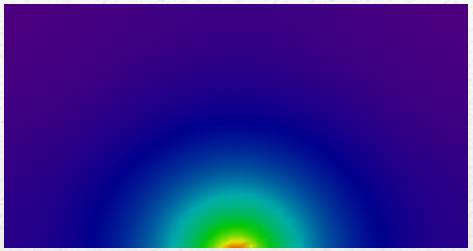


- The intensity distribution was taken from yellow line and converted to the temperature.
- The distribution depends on the power reflection coefficient weakly.
- The best simulated curve was made with emissivity coefficient ~0.15.

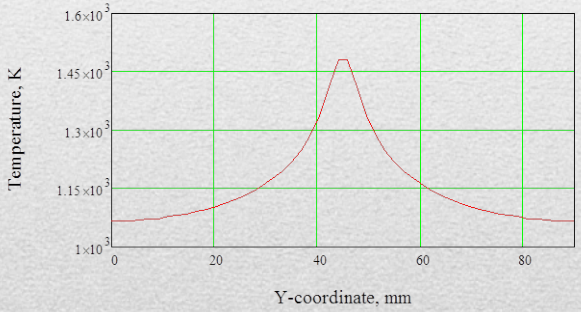
Data processing

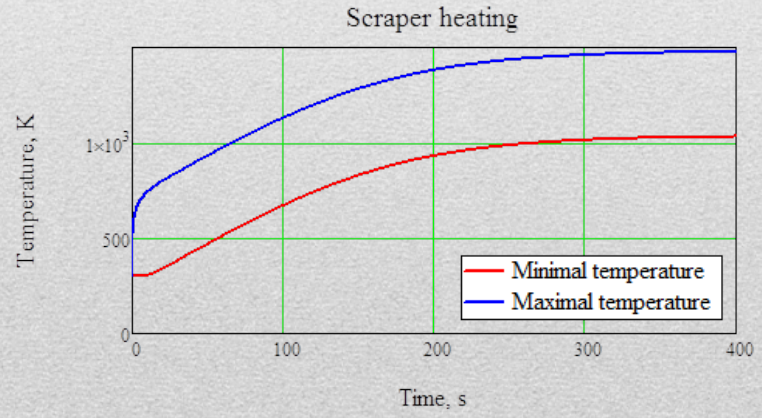
- To estimate the scraper thermal regime for PXIE, we will assume that the emissivity is equal to 0.15.
- The beam current is 10 mA, beam energy is 2.1 MeV, beam distribution is Gaussian, rms radius is 2 mm.

Distance from scraper edge to the beam center, mm	Absorbed power, W	Maximal temperature, K
6.0	28.3	1100
5.8	39	1230
5.5	62.5	1480



Temperature distribution on the scraper edge





- On the test stand, the 80 mA current, 27 keV energy, 2 mm radius beam was directed on the scraper edge.
- About 80 W of absorbed power
- Near the steady state scraper wasn't damaged

Summary

- The simplest diagnostic was developed and used to analyze the scraper thermal regimes.
- The radiation cooled scraper was tested
- The TZM emissivity was determine and was ~0.2
- The maximal power, that can be absorbed by the simplest scraper version, is ~50W.